Hydrology of Tigris river and its tributaries contributing to Hawizeh marsh

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Prasad Daggupati
Deepa Varma
Outline

• Development of SWAT model in Tigris-Euphrates basin
• Hydrological analysis of flow in Tigris and its tributaries (including Karkheh river flowing from Iran) feeding to Hawizeh marsh
• Analysis and implications of dams/water control structures
Introduction

The Tigris Euphrates River Basin

- Area: 879790 km² - largest basin in the Middle East
- Tigris: 304000 km²
- Euphrates: 503900 km²
- Karun: 71800 km²

<table>
<thead>
<tr>
<th>Country</th>
<th>Euphrates Basin</th>
<th>Tigris Basin*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Area</td>
<td>% Flow</td>
</tr>
<tr>
<td>Turkey</td>
<td>21</td>
<td>98.5</td>
</tr>
<tr>
<td>Syria</td>
<td>17</td>
<td>1.5</td>
</tr>
<tr>
<td>Iran</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iraq</td>
<td>49</td>
<td>-</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>13</td>
<td>-</td>
</tr>
</tbody>
</table>

* Data excludes Karun basin

Landuse

- Forest
  - BROADLEAF FOREST
    - Area: 119809 km²
  - NEEDLELEAF FOREST
    - Area: 1 km²
  - EVERGREEN FOREST
    - Area: 12 km²
  - MIXED FOREST
    - Area: 21 km²

- Shrubland
  - SHRUBLAND
    - Area: 309298 km²
  - BAREN/SPARSLY VEGETATED
    - Area: 191310 km²

- Agriculture
  - Agricultural Land-Row Crops
    - Area: 181515 km²
  - RICE
    - Area: 5 km²
  - Agricultural Land-Generic
    - Area: 1750 km²

- Urban
  - Residential-Medium Density
    - Area: 6858 km²
  - Residential-Low Density
    - Area: 73 km²

- Water
  - WATER
    - Area: 2486 km²

- Wetlands
  - Wetlands-Non-forested
    - Area: 1073 km²

Feeds Hawizeh Marsh

• Area: 879790 km² - largest basin in the Middle East
• Tigris: 304000 km²
• Euphrates: 503900 km²
• Karun: 71800 km²
Overview of Tigris river, tributaries and water structures feeding Hawizeh marsh

Upper Zone until Iraq border
Middle Zone until Bagdad

Legend:
- *Barrage*
- !Dam
- #*Dam Under Construction*
- $+Planned Dam
- ÛRegulator
- $+planned dam
Lower Zone until Hawizeh Marsh

Legend

- tigris_dams
- <all other values>

Type

- Û Barrage
- !( Dam
- #* Dam Under Construction
- $+ Planned Dam
- Û Regulator
- $+ planned dam
Downstream Tigris after Bagdad until Hawizeh Marsh

- Kutt barrage diverts water to Shat Al-Gharaf canal especially for irrigation
  - Final set of observed flow data available after kutt barrage
- Before Ammara barrage
  - Tigris river diverts water to 2 branches
    - Al- Eraidh (700cms) and Al Berata (700cms) to feed central marshes
- At Ammara barrage,
  - Tigris river divides into 3 branches
    - 2 branches (Al- Musharrah(150cms) and Al-Kahlaa(477cms) feeds into Al-Hawizeh marsh
    - 1 branch (360cms) heads towards Basra where it meets Euphrates
Methods
SWAT model development

Data inputs

- Watershed characterization
  - **DEM**
    - Resolution: $90 \times 90$ m
    - 940 subbasins in TU basin
      - 408 in Tigris, 454 in Euphrates, 78 in Karun
  - **Landuse landcover**
    - Resolution: $100 \times 100$ m
    - Global landuse (based on year 2000) used
      - Manual editing to make sure spatial extent of agricultural fields are represented correctly (Appendix 2)
  - **Soils**
    - FAO soils used
    - Resolution: 1:5,000,000
  - **Slope**
    - 0-5% (67% of watershed), 5-12% (9% of watershed), and >12% (23% of watershed)
  - **Weather**
    - Global weather data @ 40 by 40 KM resolution
      - Daily data for 32-year period from 1979 to 2010
      - 1272 weather stations in the river basin
  - **HRU delineation**
    - 5/12/10% thresholds for landuse, soil, slope
      - All agricultural lands were exempt
    - Finally **9088 HRU’s** in TU basin

Appendix 1 gives information on SWAT model.
## Dams

<table>
<thead>
<tr>
<th>Water control structures</th>
<th>Euphrates</th>
<th>Tigris</th>
<th>Karun</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dams</td>
<td>14</td>
<td>11</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>Planned dams</td>
<td>2</td>
<td>10</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Dams under construction</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Barrage/regulators</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Total Dams</td>
<td>16</td>
<td>22</td>
<td>9</td>
<td>47</td>
</tr>
<tr>
<td>Total Barrage/regulators</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>8</td>
</tr>
</tbody>
</table>

### Tigris basin
- 1950 - 1970: 3
- 1971 - 1979: 1
- 1980 - 1989: 2
- 1990 - 1999: 4
- 2000 - 2010: 1
- 2011 - 2020: 11

### Water control structures in country

<table>
<thead>
<tr>
<th>Water control structures in country</th>
<th>Euphrates</th>
<th>Tigris</th>
<th>Karun</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>current</td>
<td>planned</td>
<td>current</td>
<td>planned</td>
</tr>
<tr>
<td>Turkey</td>
<td>7</td>
<td>2</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Syria</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Iraq</td>
<td>0</td>
<td>1</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Iran</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>2</td>
<td>16</td>
<td>11</td>
</tr>
</tbody>
</table>

### Legend
- Barrage
- Dam
- Dam Under Construction
- Planned Dam
- Regulator

More information on dams is presented in appendix 3

- Dam operational information
  - Start date, Surface area, volume, operational logistics
    - Wikipedia and other cited literature
  - Manual adjustments needed to be made
    - Some data in Wikipedia were wrong
      - Eg. Surface area of Tartar lake 2800 Sq.KM, however observation on aerial image shows 1800 Sq.KM
### Calibration

#### Statistical and graphical evaluation

<table>
<thead>
<tr>
<th>Gauge station</th>
<th>R2</th>
<th>NSE</th>
<th>PBIAS</th>
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</thead>
<tbody>
<tr>
<td>Greater Zab upstream (1982-1990)*</td>
<td>0.67</td>
<td>0.65</td>
<td>9</td>
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<tr>
<td>Greater Zab downstream (1982 –1990)</td>
<td>0.67</td>
<td>0.65</td>
<td>10</td>
</tr>
<tr>
<td>Lesser Zab upstream (1982-1990)</td>
<td>0.71</td>
<td>0.64</td>
<td>-25</td>
</tr>
<tr>
<td>Diyala upstream ((1982-1990)</td>
<td>0.68</td>
<td>0.62</td>
<td>14</td>
</tr>
<tr>
<td>Karkheh below reservoir (1990 -1999)</td>
<td>0.68</td>
<td>0.62</td>
<td>14</td>
</tr>
<tr>
<td>Tigris below Mosul dam (1985-1994)</td>
<td>0.51</td>
<td>0.5</td>
<td>-13</td>
</tr>
<tr>
<td>Tigris before Samara barrage (1985-1994)</td>
<td>0.71</td>
<td>0.7</td>
<td>10</td>
</tr>
<tr>
<td>Tigris above Bagdad (1985-1994)</td>
<td>0.37</td>
<td>0.09</td>
<td>8</td>
</tr>
<tr>
<td>Tigris below Kutt barrage (1989-2001)</td>
<td>0.72</td>
<td>0.2</td>
<td>-14</td>
</tr>
</tbody>
</table>

R2 > 0.6 ---> good  
NSE > 0.5 ---> good  
Pbias < 15% ---> good

* Time period of calibration based on best observed data available without data interruptions

### Observed vs Simulated Streamflow

- **Greater Zab upstream (t7)**
- **Tigris below Kutt barrage (t7)**

#### 2000-2010 simulated – 800mcm

- **Observed**
- **Simulated**
- **Linear (Simulated)**
Results
• Flow into Hawizeh marsh from Karkheh River

2500 ha, 5900 mcm
Annual Water budgets in 80’s Kutt Barrage

Average 80’s

- Tigris
- Greater Zab
- Lesser Zab
- Diyala
- Karkheh
- Bagdad
- Kutt Barrage
- Shatt al Gharaf
- Al Erefid
- Al Bararra
- Amarah

Low 80’s

- Tigris
- Greater Zab
- Lesser Zab
- Diyala
- Karkheh
- Bagdad
- Kutt Barrage
- Shatt al Gharaf
- Al Erefid
- Al Bararra
- Amarah

High 80’s

- Tigris
- Greater Zab
- Lesser Zab
- Diyala
- Karkheh
- Bagdad
- Kutt Barrage
- Shatt al Gharaf
- Al Erefid
- Al Bararra
- Amarah

All numbers above are average annual flow volume in mcm

Nature Iraq report: 5000, 4000, 2500 mcm to reflood 75, 50 and 25% with evaporative demand of 3000, 2000, 1500 mcm and with constant outflow of 2000 mcm
Annual Water budgets in 90’s until Kutt Barrage

Average 90’s

Tigris

Mosul

15000

Greater zab

8000

Lesser Zab

4000

Samarra barrage

9000

Kutt barrage

22000

Bagdad

2800

Diyala

19000

Tartar

9000

Samarra barrage

18000

Kutt barrage

22000

Bagdad

2800

Diyala

Low 90’s

Tigris

Mosul

2500

Greater zab

3400

Lesser Zab

800

Samarra barrage

1000

Kutt barrage

1000

Diyala

6000

Tartar

1000

Samarra barrage

1000

Diyala

High 90’s

Tigris

Mosul

23000

Greater zab

6000

Lesser Zab

5000

Samarra barrage

14000

Kutt barrage

29000

Bagdad

1800

Diyala

26000

Tartar

14000

Samarra barrage

22000

Bagdad

1800

Diyala

All numbers above are average annual flow volume in mcm

Nature Iraq report: 5000, 4000, 2500 mcm to reflood 75, 50 and 25% with evaporative demand of 3000, 2000, 1500 mcm and with constant outflow of 2000 mcm
Annual Water budgets in 2000’s Kutt Barrage

Average 2000’s

Mosul

Tigris

Greater zab

Lesser Zab

Diyala

Bagdad

Shatt al Gharaf

Nature Iraq report: 5000, 4000, 2500 mcm to reflood 75, 50 and 25% with evaporative demand of 3000, 2000, 1500 mcm and with constant outflow of 2000 mcm

Low 2000’s

Mosul

Tigris

Greater zab

Lesser Zab

Diyala

Bagdad

Shatt al Gharaf

High 2000’s

Mosul

Tigris

Greater zab

Lesser Zab

Diyala

Bagdad

Shatt al Gharaf

All numbers above are average annual flow volume in mcm
Annual Water budgets below Kutt Barrage

1. **Average 80's**
   - Tigris to Kutt barrage: 40000 mcm
   - 25% of 100000 mcm
   - Karkheh to Al Betarra to Amarah: 5000, 5000, 5000 mcm
   - 2200 mcm
   - Amaranth: 2400 mcm
   - 60% of 24000 mcm

2. **Low 80's**
   - Tigris to Kutt barrage: 16000 mcm
   - 25% of 64000 mcm
   - Karkheh to Al Betarra to Amarah: 4300, 4300, 4300 mcm
   - 2200 mcm
   - Amaranth: 2400 mcm
   - 53000 mcm
   - 50% of 106000 mcm

3. **High 80's**
   - Tigris to Kutt barrage: 53000 mcm
   - 25% of 212000 mcm
   - Karkheh to Al Betarra to Amarah: 13250, 13250, 13250 mcm
   - 6000 mcm
   - Amaranth: 7950 mcm
   - 50% of 106000 mcm

4. **Average 90's**
   - Tigris to Kutt barrage: 18000 mcm
   - 25% of 72000 mcm
   - Karkheh to Al Betarra to Amarah: 7000, 7000, 7000 mcm
   - 2200 mcm
   - Amaranth: 2400 mcm
   - 10800 mcm
   - 30% of 36000 mcm

5. **Low 90's**
   - Tigris to Kutt barrage: 7000 mcm
   - 25% of 28000 mcm
   - Karkheh to Al Betarra to Amarah: 2500, 2500, 2500 mcm
   - 2200 mcm
   - Amaranth: 1050 mcm
   - 13200 mcm
   - 25% of 52800 mcm

6. **High 90's**
   - Tigris to Kutt barrage: 22000 mcm
   - 25% of 88000 mcm
   - Karkheh to Al Betarra to Amarah: 13200, 13200, 13200 mcm
   - 800 mcm
   - Amaranth: 3300 mcm
   - 5500 mcm
   - 25% of 22000 mcm

7. **Average 2000's**
   - Tigris to Kutt barrage: 8000 mcm
   - 25% of 32000 mcm
   - Karkheh to Al Betarra to Amarah: 5000, 5000, 5000 mcm
   - 2200 mcm
   - Amaranth: 750 mcm
   - 4800 mcm
   - 25% of 19200 mcm

8. **Low 2000's**
   - Tigris to Kutt barrage: 5000 mcm
   - 25% of 20000 mcm
   - Karkheh to Al Betarra to Amarah: 2700, 2700, 2700 mcm
   - 2200 mcm
   - Amaranth: 750 mcm
   - 5000 mcm
   - 25% of 20000 mcm

9. **High 2000's**
   - Tigris to Kutt barrage: 13000 mcm
   - 25% of 52000 mcm
   - Karkheh to Al Betarra to Amarah: 3250, 3250, 3250 mcm
   - 2200 mcm
   - Amaranth: 1950 mcm
   - 7800 mcm
   - 25% of 31200 mcm

**Additional Information:**
- Nature Iraq report: 5000, 4000, 2500 mcm to refill 75, 50 and 25% with evaporative demand of 3000, 2000, 1500 mcm and with constant outflow of 2000 mcm.

All numbers above are average annual flow volume in mcm.
Flow intensity, duration, probability below Kutt Barrage

After Kutt barrage

Flow diversion into Hawizeh marsh

Flow diversion above Amarah barrage

Flow of tigris towards Basra
## Dams

### Current Dams

<table>
<thead>
<tr>
<th>Current Dam</th>
<th>Volume (mcm)</th>
<th>Inflow (mcm)</th>
<th>Outflow (mcm)</th>
<th>% reduction</th>
<th>Evaporation (mcm)</th>
<th>evap/vol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batman</td>
<td>1100</td>
<td>1105</td>
<td>874</td>
<td>21%</td>
<td>50</td>
<td>5%</td>
</tr>
<tr>
<td>Dicile</td>
<td>580</td>
<td>674</td>
<td>659</td>
<td>2%</td>
<td>24</td>
<td>4%</td>
</tr>
<tr>
<td>Kralkize</td>
<td>1920</td>
<td>342</td>
<td>305</td>
<td>11%</td>
<td>54</td>
<td>3%</td>
</tr>
<tr>
<td>Mosul</td>
<td>11110</td>
<td>18799</td>
<td>17972</td>
<td>4%</td>
<td>416</td>
<td>4%</td>
</tr>
<tr>
<td>Dokan</td>
<td>6800</td>
<td>5799</td>
<td>4587</td>
<td>21%</td>
<td>309</td>
<td>5%</td>
</tr>
<tr>
<td>Dibbis</td>
<td>4000</td>
<td>4953</td>
<td>3932</td>
<td>21%</td>
<td>154</td>
<td>4%</td>
</tr>
<tr>
<td>Hemrin</td>
<td>2500</td>
<td>3318</td>
<td>2670</td>
<td>20%</td>
<td>78</td>
<td>3%</td>
</tr>
<tr>
<td>Derbinkhan</td>
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<td>3250</td>
<td>2866</td>
<td>12%</td>
<td>142</td>
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<tr>
<td>Karkheh</td>
<td>5900</td>
<td>1978</td>
<td>1086</td>
<td>45%</td>
<td>40</td>
<td>1%</td>
</tr>
<tr>
<td>Tartar</td>
<td>11000</td>
<td>9000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>47910</strong></td>
<td><strong>49219</strong></td>
<td><strong>35519</strong></td>
<td><strong>21%</strong></td>
<td><strong>3529</strong></td>
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</table>

### Future Dams

<table>
<thead>
<tr>
<th>Future Dams</th>
<th>River</th>
<th>Country</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taqtaq</td>
<td>Lesser Zab</td>
<td>Iraq</td>
<td>2858</td>
</tr>
<tr>
<td>Bekhme</td>
<td>Greater Zab</td>
<td>Iraq</td>
<td>8300</td>
</tr>
<tr>
<td>Bakeerman</td>
<td>Greater Zab</td>
<td>Iraq</td>
<td>500</td>
</tr>
<tr>
<td>Mandava</td>
<td>Greater Zab</td>
<td>Iraq</td>
<td>2000</td>
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<tr>
<td>Hakkari</td>
<td>Greater Zab</td>
<td>Turkey</td>
<td>2000</td>
</tr>
<tr>
<td>Garzan</td>
<td>Trib upper tigris</td>
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<td>1970</td>
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<td>Dilini</td>
<td>Trib upper tigris</td>
<td>Turkey</td>
<td>200</td>
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<td>Turkey</td>
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<td>Cizie</td>
<td>Upper tigris</td>
<td>Turkey</td>
<td>200</td>
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<tr>
<td>Illisu</td>
<td>Upper tigris</td>
<td>Turkey</td>
<td>10410</td>
</tr>
</tbody>
</table>

### Dam effects

- **Flow out with reservoir**
- **Flow out without reservoir**
- **Volume with irrigation**
- **Volume without irrigation**

---

**Graph**

- **X-axis**: Year (2000 to 2010)
- **Y-axis**: Flow (cums) and Volume (mcm)

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**Legend**

- Black line: Flow out with reservoir
- Blue line: Flow out without reservoir
- Orange line: Volume with irrigation
- Cyan line: Volume without irrigation
Current and Post Dams

**Average 2000’s - Current**

- Tigris
  - 8000
  - 9000
  - 1200
  - 5000
- Greater Zab
  - 4000
  - 1000
  - 14000
- Tartar
  - 4000
- Samarra barrage
  - 1000
  - 3000
- Diyala
  - 1200
- Bagdad
  - 10000
- Kutt barrage
  - 900
- Shatt al Gharaf
  - 5000
- Al Qadisiyah
  - 4800
- Al Battera
  - 2000
- Karkheh
  - 900

**Average 2000’s – Post dams**

- Tigris
  - 6000
  - 7000
  - 2000
  - 10000
- Greater Zab
  - 2000
  - 1000
  - 10000
- Lesser Zab
  - 1000
  - 7000
- Tartar
  - 3000
- Samarra barrage
  - 1000
  - 7000
- Diyala
  - 1000
- Bagdad
  - 4000
- Kutt barrage
  - 5000
- Shatt al Gharaf
  - 4000
- Al Qadisiyah
  - 2400
- Al Battera
  - 1000
- Karkheh
  - 900

*Assumptions based on current dam sizes, inflow and outflow calculations, 50% reduction*
Summary

- Decreasing trend of flow in tributaries and main stem
  - 65% and 80% decrease below kutt barrage in 90’s and 2000’s compared to 80’s
  - 0% and 82% decrease in Karkheh in 90’s and 2000’s compared to 80’s
    - Decrease mainly due to decrease in rainfall and construction of water structures such as dams and water diversions

- 10%, 30 % and 80% of water available to flood the Hawizeh marsh to 75% , 50% and 25% of original size in 2000’s

- Current and proposed dams plays a major role in water availability to Hawizeh marsh
  - Evaporation in current dams is equivalent to water needed to re-flood marshes close to 50% of original size
  - Karkheh dam reduces flow by 45%
  - Future dams such as Illusu on Tigris; behme, hakkari and mandava on Greater Zab will have huge impacts
    - Roughly 50% reduction compared to 2000 and 90% compared to 80’s

- Proper management of dams, water diversions and irrigation will help in improving water availability to Hawizeh marsh
Thank you